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The Final Proceedings for International Workshop on Laser and Fiber-Optic Network Modeling, 25 May 1999 - 25 May 1999

This is an interdisciplinary conference. Topics include solid-state physics, semiconductor physics, fiber-optics components and networks, nonlinear effects in active and passive optical devices, dispersive media and beam propagation in optical waveguides, modelling of physical processes in semiconductor, solid-state, and gas lasers, new coherent optical sources for the systems of transmission, storage, and analysis of information.

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LFNM'99

May 25, 1999, Kharkov, Ukraine
Kharkov Technical University of Radio Electronics, Conference Hall

International Workshop on
LASER AND FIBER-OPTIC NETWORK MODELLING

Organized and sponsored by
IEEE AP/MTT/ED/AES/GRS/LEO Societies East Ukraine Joint Chapter

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IEEE Lasers and Electro-Optics Society
European Office of Aerospace Research and Development,
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Workshop Program

8:00 - 10:00	Registration of LFNM'99 Participants
10:00	**OPENING CEREMONY**
Plenary Session 1	Chairman M.M. Bykov
10:15	**«Importance of the Coulomb effect and ordering in the design of S-based mid-infrared MQW emitting structures»**, P. Christol and P. Bigenwald, laboratoire de Physique des Materiaux (LPM), Faculte des Sciences d'Avignon, Avignon France, D.A. Yarekha, A. Wilk, Y. Pouillard, A.N. Baranov and A. Joullie centre d'Electronique et de Microoptoelectronique de Montpellier (CEM2), Universite de Montpellier II, France, A. Stein, A. Behres and K. Heime, Institut für Halbleitertechnik, RWTH Aachen, Germany
10:45	**«Nonlinear interactions of waves in optical layered systems»**, A.A. Bulgakov, Institute of

Radiophysics and Electronics, National Academy of Sciences of Ukraine, Kharkov, Ukraine

11:15 **«Formation of beams with uniform intensity profiles in laser cavities»**, O.V.Gurin, V.A. Maslov, I.M.Militinski, V.A.Svich, A.N.Topkov, Kharkiv State University, Ukraine

11:45 Coffee Break

Plenary Session 2 Chairman I.A. Sukhoivanov

12:15 **«Extraction of model parameters for quantum well laser diodes from DC and small signal measurements»**, M.Krieg, V.Lysak, W.Freude, Institut f. HF-Technik und Quantenelektronik, University Karlsruhe, Germany

12:45 **«Optical feedback and mode selection in semiconductor lasers having a resonator with a dispersion element»**, I.S. Manak, V.K.Kononenko, S.V.Nalivko, Belorusian State University, Minsk, Belarus

13:15 **«Scattering of an electromagnetic wave on an amplifying optical fiber»**, N.G. Kokody, Kharkov State University, Ukraine

13:45 Coffee Break

14:15 - 15:45 **Poster Session**

Lasers and active elements

1. **«Mathematical modelling of generation regimes of lasers on asymmetric quantum-well heterostructures»**, A.A. Afonenko, V.K. Kononenko, I.S. Manak, Belorusian State University

2. **«New oscillation mode of the CO_2 laser with saturated absorber»**, V. Nevdakh, L.Orlov, P. Gaiko, Institute of Physics, Academy of Sciences of Belarus, Minsk, Belarus

3. **«Investigation of dynamic behavior of surface emitting semiconductor lasers»**, I.A. Sukhoivanov, Kharkov Technical University of Radio Electronics, Ukraine

4. **«Modelling of kinetic processes in the CO_2 laser with phototropic modulator»**, M.M. Bykov, N.G. Skrynyk, Kharkov Technical University of Radio Electronics, Ukraine

5. **«Study of the main charcteristics of a dye laser under different temperature regimes of an active element»**, M.I. Dzyubenko, V.V. Maslov, V.P. Pelipenko, V.V. Shevchenko, Institute of Radiophysics and Electronics NAN of Ukraine, Kharkov, Ukraine

6. **«Geometrical optics of axially-symmetric non-uniform amplifying medium»**, V.Shevchenko, Institute of Radiophysics and Electronics NAN of Ukraine, Kharkov, Ukraine

7. **«New program interface for the laser performance investigation», M. V. Samokhvalov, A. N. Manschura, A.V. Kublik, I. A. Sukhoivanov,** Kharkov Technical University of Radio Electronics, Kharkov, Ukraine

8. **«Dependence of parameters of photodetector on the structure of p-i-n diode»**, A.I. Tereshchenko, S. O. Martynenko, Kharkov Technical University of Radio Electronics, Ukraine

9. **«Application of the Fourier transformation for the analysis of the SQW laser diode transfer characteristics»**, O. Manzhura, Kharkov Technical University of Radio Electronics, Ukraine

Passive Elements and Adders

10. **«Two-dimensional integral equations for the analysis of optical waveguides»**, Michael V. Davidovich, Saratov State Technical University, Russia

11. **«Comparison of validity of the wave and beam models of propagation in the multiport floated fiber-optic distributors-adders»**, M. I. Prokofyev, P. A. Demyanenko, V. I. Naidenko, SRC «Tesis» of the National Technical University of Ukraine «Kiev Politechnical Institute», Kiev, Ukraine

12. **«Accounting of some restrictions for the threshold sensitivity and measurement error in the pulse fiber-optic accelerometers»**, P.P. Demyanenko, SRC «Tesis» of the National Technical University of Ukraine «Kiev Politechnical Institute», Kiev, Ukraine

13. **«Principles and methods of electronic and optical gyroscopic devices»**, B. F. Alekseyev, P. A. Demyanenko, M. I. Prokofyev, SRC «Tesis» of the National Technical University of Ukraine «Kiev Politechnical Institute», Ukraine

14. **«Radiation intensity analysis method and its application in manufacturing fiber-optic components»**, I.I. Nevlyudov, A.I. Filipenko, Kharkov Technical University of Radio Electronics, Ukraine

15. **«Propagation of nonlinear optical pulses in optical media with a set of identical plane-parallel light guides»**, I.V. Gerasimchuk, Kharkov State University, Ukraine, A.S. Kovalev, Verkin's Physic-Technical Institute of Low Temperatures, NAN of Ukraine, Kharkov, Ukraine

16. **«Beam model of radiation propagation in biconical area of multiport floated fiber-optic distributors-adders»**, M.I. Prokofyev, SRC «Tesis» of the National Technical University of Ukraine «Kiev Politechnical Institute», Ukraine

17. **«Absolute cryogenic receiver as a standard laser radiation receiver»**, I. A. Nazarenko, M. M. Bykov, M. P. Kukhtin, Kharkov Technical University of Radio Electronics, Kharkov, Ukraine

18. **«Control of distribution of monochromatic radiation intensity near the focal point»**, V.N. Bykov, A.S. Bilchinski, Ye. D. Prilepski, Kharkov Military University, Ukraine

19. **«Estimation of application potentialities of «geometric parallelism» in the identification algorithms at optical and radiometric images»**, M.G. Shokin, Kharkov Military University, Ukraine

20. **«Reduction of discretization error in the digital correlation-extreme navigation systems»**, A.M. Grichanyuk, Kharkov Military University, Ukraine

21. **«Analytical approach to the fine structure of diffraction anomalies in the resonance diffraction»**, N.A. Balakhonova, Kharkov Military University, Ukraine

22. **«Transformation of polarization through the resonance diffraction»**, N.A. Balakhonova, A.A. Kats, A.V. Kats, I.S. Spevak, Kharkov Military University, Ukraine

23. **«Modelling of processes in electrochemiluminescence emitting devices and their applications»**, I.B. Svir', A.I. Bykh, Kharkov Technical University of Radio Electronics, Ukraine

24. **«Total suppression of the specular reflection through the resonance diffraction from highly reflecting surface»**, N.A. Balakhonova, A.A. Kats, A.V. Kats, I.S. Spevak, Kharkov Military University, Ukraine

16:00 **Closing Plenary Session**

16:10 **Welcome Party**: university cafeterium, 2-nd floor

List of Participants of the international workshop «LASER AND FIBER-OPTIC NETWORK MODELLING»

Kharkov, Ukraine, May 25, 1999

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66	Podoprigora A.	Kharkov Technical University of Radio Electronics, Ukraine	√
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68	Karapysh S.I.	Kharkov Technical University of Radio Electronics, Ukraine	√

LFNM'99

Digest

International Workshop on

LASER AND FIBER-OPTIC NETWORK MODELLING

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INVITED PAPERS

Importance of the Coulomb effect and ordering in the design of Sb-based mid-infrared MQW emitting structures

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Uncooled mid-infrared laser diodes emitting in the 2-5 µm wavelength range are of great importance for environmental gas sensing applications. Impressive progress has been achieved recently in this wavelength range on Sb-based multi-quantum-well (MQW) laser structures [1].

In this work, we have considered two compressively strained heterostructures : - GaSb-based GaInAsSb-GaSb QWs for emission in the wavelength range 2-3 µm - InAs-based InAsSb-InAs(P) QWs for emission in the wavelength range 3-5 µm GaInAsSb/GaSb QWs : We have grown GaInAsSb/GaSb quantum well lasers on GaSb substrates by MBE. The devices exhibited laser emission at 2.35 µm and 2.65 µm at 23ƒC with respective threshold current densities of 0.6 kA/cm2 and 3 kA/cm2 [2,3]. In these structures which have a type-II band aligment the electrons localised in the GaInAsSb wells strongly pull the holes from the adjacent GaSb barriers due to Coulomb attraction. Such an interaction induces a modification of the band structure near the heterointerfaces. By solving the coupled set of Poisson and Schr–dinger equations, we demonstrate that this change generates a strong enhancement of the oscillator strength (typically 40% for a carrier injection of 1.1012 cm-2), which explains why lasing occurs with good characteristics in these type-II quantum wells.

InAsSb/InAs(P) QWs : Gain-guided InAsSb/InAs MQW lasers and LEDs based on InAsSb/InAsP quantum wells grown by MOVPE on InAs substrates have showngood characteristics (laser operation up to 210 K at 3.8-3.9 µm and LED output power of 80 µW around 4 µm at room temperature) [4]. These QW structures theoretically have a type-II band alignment [5]. Under this assumption the emitted wavelength could not be found from classical calculations using the k-p formalism and the envelope function approximation. It has been shown that some InAsSb samples grown by MOVPE exhibit spontaneous CuPt-type ordering [6]. The ordering reduces the band gap, primary by lowering the conduction band minimum energy of the strained alloy. We show that the main effect of ordering is to reverse the sign of the conduction band offset, leading to a type-I band aligment. The optical transitions calculated using the ordering-induced band gap reduction agree in a

satisfactory manner with the reported data [4] and with our photoluminescence measurements from strained InAsSb/InAs and strain-balanced InAsSb/InAsP MQWs emitting up to 5.3 µm.

This work was partially supported by EC : BRITE-EURAM III , BRPR CT 97 0466 ADMIRAL

[1] H.K. Choi and P.S. Zory ed, « MID-IR SOURCES, parts II and III » in Proc. of the SPIE, vol. 3284, (1998).
[2] A.N. Baranov et al. Electron. Lett. 32 (1996) 2279
[3] Y. Cuminal et al. to be published in Semicond. Sci. Technol.
[4] R.M. Biefeld et al. IEEE J. Select. Topics Quantum Electron. 3 (1997) 739
[5] Y.B. Li et al Phys. Rev. 55 (1997) 4589
[6] D.M. Follstaedt et al. J. Electron. Mater. 24 (1995) 819

NONLINEAR INTERACTIONS OF WAVES IN OPTICAL LAYERED SYSTEMS

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Investigation of nonlinear processes of interaction of waves in inhomogeneous media show that the efficiency of the frequency conversion increases at the frequencies near the passband boundaries of the structure. This work studies nonlinear excitation of the second harmonic wave in a periodical structure consisting of alternating layers of uniaxial nonlinear and isotropic linear dielectrics. Here we present a technique of analysis of layered structures that enables us to reduce the original problem to the well-known set of coupled equations.

It is stated that the phase matching (or satisfying the laws of synchronism) is achieved due to the Bragg resonances associated either with a single layer or with the period of the structure. Besides, these laws are satisfied for a structure that can be characterized by an effective value of dielectric permittivity.

The second harmonic is excited by a pumping incident wave that hits periodocal structure from a homogeneous half-space. In the case of a periodic structure characterized by an effective dielectric permittivity, the transmission and reflection coefficients are independent of the frequency. In this case, nonlinear resonant interaction occures in a frequency range instead at separate isolated frequencies. Hence, a frequency conversion of a given continous spectrum is possible.

Such investigations are of great interest because of their practical use in specroscopy, detection of parameters of periodic structures, and also in multiplication and mixing of optical signals.

Formation of beams with uniform intensity profiles in laser cavities

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A review of fundamental intracavity methods of a uniform spatial field distribution formation in quantum oscillators is given. A novel intracavity method proposed by the authors is considered in detail. It differs from the others by a simple modification of the resonator, small additional losses and by guaranty of single-mode generation. This method is based on the use of a reflector with discretely distributed absorbing or phase–shifting inhomogeneities in the scheme of open confocal cavity (CC) or generalised confocal cavity (GCC). Existence of mode with intensity distribution similar to a uniform function on one of the reflectors and the Fourier transform of this function on another reflector in such a system have been substantiated by the application of the Fourier optics concepts to transformations of a set of integral equations for CC and GCC with nonuniform mirrors. Then a field with a uniform spatial intensity distribution can be formed both immediately at the output aperture of a laser and in the far zone. The mentioned properties enable one to classify the found type of oscillations as the Fourier mode. The presence of such a mode is confirmed by the results of numerical solution of the obtained equations. An investigation of characteristics of four lower-loss modes (two even–symmetric and two odd–symmetric) was carried out by the matrix method. Dependences of intensity distributions and lower-mode power losses on the Fresnel number of the cavity, and on the number and the size of inhomogeneous areas at the mirror aperture have been studied. An experimental model of a CO_2–laser has been developed on the basis of an open GCC with an stepped amplitude mirror. Experimental confirmation is reported of the generation of such a mode with a quasi–uniform beam at the output of a CO_2–laser. Stability of this oscillation type with respect to the changes in geometrical parameters of the cavity has been investigated.

Extraction of model parameters for quantum well laser diodes from DC and small signal measurements

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For the design of photonic networks, numerical simulations are of paramount importance. Since the calculation time increases greatly with the number of network components and with the transmission length, the relevant numerical models have to be chosen carefully with respect to computing time and model accuracy.

Laser diodes are key components in optical communications. Rate equation based models have proved to be a good compromise between an adequate physical representation and an acceptable computing time. However, due to the large number of parameters even for a plain two-equation description in terms of total photons and carriers, the extraction of appropriate model parameters from measured data represents a challenging problem.

For quantum-well laser diodes we present a new parameter extraction method based on the measurement of the power-to-current characteristics and the small signal response function. Parasitic elements, which are not sensitive to a variation of the operating point, are eliminated by relating data registered above laser threshold to data near threshold [1].The method allows the exact evaluation of all rate equation parameters.

Moreover, by varying the operating point for the small signal response function, the method can be used to assess the validity of different rate equation models for an individual laser device. To this end, the parameters for different models are extracted and compared. The best model has the least dependence of its parameters on the operating point.

The method is demonstrated by the evaluation of experimental data presented in [2], comparing three rate equation models, which differ in gain nonlinearities and carrier transport.

[1] P. A. Morton, T. Tanbun-Ek, R. A. Sergent, P. F. Sciortino, Jr. and D. L. Coblentz, ``Frequency response subtraction for simple measurement of intrinsic laser dynamic properties". IEEE Photonic Technol. Lett., Vol. 4, pp. 133--137, 1992.

[2] J. C. Cartledge, R. C. Srinivasan, ``Extraction of DFB laser rate equation parameters for system simulation purposes". J. Lightwave Technol., Vol. 15, pp. 1--100, 1997.

Optical feedback and mode selection in semiconductor lasers having a resonator with a dispersion element

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The control of the spectrum emission of laser diodes is an important problem under various conditions of their performance. In the paper, the output power characteristics of the asymmetric multiple quantum-well heterostructure lasers are examined in detail and the usage of selective external cavities for lasing wavelength control is discussed.

In the lasers with an asymmetric quantum-well heterostructure, the active region contains quantum wells of different widths and semiconductor components. Amplifying quantum-well layers are separated by the barrier layers with a modified potential profile. Such a design of laser structures provides a nonuniform current excitation of the quantum wells and results in the broad-band gain spectra.

The control of the laser emission spectra was analyzed for an external cavity with a diffraction grating and a tuning mirror. Dispersion characteristics of the cavity were optimized to enhance the laser power and to obtain the stable output in the whole tuning range.

For the spectral interval near the wavelength of 820 nm, the GaAs – AlGaAs system is most suitable. In this case, the width of the gain band reaches 50 nm and the tuning curve is practically flat at the output power of about 10 mW. Therefore, the lasing occurs in a single-mode regime without the mode hops.

Scattering of an electromagnetic wave on an amplifying optical fiber

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Interaction of electromagnetic radiation with the amplifying media is a well studied branch of electromagnetics because of applications in lasers, masers and other devices of the quantum electronics. But the problems of the diffraction of electromagnetic waves on the bodies which amplify the radiation are not enough investigated.

The effects appearing can be exhibited in the regions of space where the maser effect arises. They can find application in microwave and optical engineering.

The reflection and trasmittion of radiation through a slab of material which amplifies the radiation (due to having a complex refraction coefficient with the positive imaginary part) is considered. Then the problem of diffraction of a plane electromagnetic wave on an amplifying circular cylinder is investigated. The factors of extinction, scattering and radiation pressure are calculated. The form of the scattering diagram is found.

The extinction has approximately the same character as for an absorbing cylinder, the scattering is increased. New resonances appear. The form of the scattering diagrams changes. The radiation pressure therefore changes also. It can even change the direction.

These effects will apparently exist in the diffraction of electromagnetic wave on the bodies having the other shapes: sphere, ellipsoid, etc.

POSTER SESSION

P1

Mathematical modeling of generation regimes of lasers on asymmetric quantum-well heterostructures

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The usage of asymmetric quantum-well heterostructures is an efficient way of widening the functionality of semiconductor devices. Asymmetric heterostructure lasers comprise two or more quantum-well layers differing in the width or alloy composition. Such a design is suitable for achieving the laser operation at higher optical wavelengths.

Mathematical modeling of dynamic processes in asymmetric quantum-well lasers has been performed by using the rate equation theory. It has been shown that the modes of regular pulse generation at two or three higher optical wavelengths in the range of 790 to 850 nm can be realized in the GaAs-$Al_xGa_{1-x}As$ system with the bi- or triple-quantum-well heterostructures having suitable configuration and doping of the active and barrier layers. It is found that character of oscillation process is highly affected by the injection coupling between the quantum wells. Calculations of the injection efficiency and the band profile of asymmetric quantum-well heterostructures were done by using the self-consistent integration of the Poisson equation and continuity equations for the electron and hole currents taking into account the processes of tunnelling and ballistic transfer. The influence of the heterostructure parameters and the pump current density on the frequency, duration, and amplitude of light pulses and on the phase shift between the pulses of radiation at different wavelengths has been studied in detail.

P3

Investigation of dynamic behavior of surface emitting semiconductor lasers

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The given work is devoted to the problem of numerical simulation and analysis of the vertical cavity surface emitting lasers (VCSEL's) with the purpose of improving their high-speed performances. We investigated the InGaAs/GaAs VCSEL.

VCSEL's /1/ offer excellent performance in the applications such as optical interconnects, optical networks, and optical signal processing systems. In a number of VCSEL's application (in optical data links and 2D optical switching), the thermal stability is important. Therefore, investigation of device performance must be given with account of thermal properties. The temperature effects and carrier distribution have different contribution to the behavior of the transverse modes /4/. First of all, VCSEL has a current spreading, also, temperature difference between active region and substrate lead to the index increasing.

The analysis of the transverse mode in VCSEl's that takes into account the distributions of carriers, optical field and especially temperature is essential.

In this work, the analysis of the VCSEL with the help of the mathematical model based on the beam propagation method are presented. The simplified model is composed from the solutions of the scalar wave equation (for the presentation of the field distribution in the cavity), the diffusion equation for the carrier density in the active layer, and the thermal conductance equation. This model yields an exact solution for the optical fields in the resonator, enables one to calculate the output power and the second mode suppression, takes into account the spatial hole burning effects. With the aid of such a model, the influences of injected current, aperture and diameter of the oxide window, temperature effects on the transverse mode in VCSEL's were investigated.

Then, the dynamic behaviour, modulation characteristics and the influence of the temperature effect with the aid of extended set of the rate equations for VCSEL have been examined. It is shown that the increase of amplitude large signal injection current and the radius of the window reduces the laser bandwidth and increases the laser warm-up time.

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/1/ /2/ C.J. Chang-Hasnain, J.P. Harbison, G. Hasnain, A.C. Von Lehmen, and N.G. Stoffel, "Dynamic, polarization, and transverse mode characteristics of VCSEL's," *IEEE J. Quantum Electron.*, vol. 32, pp. 1402-1409, 1991.

P4

Modelling of kinetic processes in the CO_2 laser with phototropic modulator

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The purpose of development of a mathematical model of the laser is a full mathematical description of all possible parameters and processes. Such a model can be used to improve characteristics of lasers on the basis of numerical simulation.

The given work is devoted to consideration of a laser which does not require additional managing devices and is used to form signal pulses of laser radiation or their series. It is based on the usage of nonlinear resonant radiation-absorbing materials. It is possible to form the short laser pulses with a rather small duration to period ratio with the aid of phototropic shutters.

The kinetics of CO2 gas laser with interior resonance phototropic cell can be investigated based on the equations which describe the time variations both of the intensity of laser radiation and of the inversed population of active and passive media.The equatiions characterizing the kinetics of processes in CO2 laser with a phototropic shutter are reduced to a set of ordinary differential equations.

The results of modelling have confirmed theoretical conclusions on the determination of operational modes of CO2 laser with phototropic modulator that depend on the selected parameters of this laser.

P5

Study of main characteristics of a dye laser under different temperature regime of an active element

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An experimental investigation of the spatial-angular characteristics of repetitively pulsed flashlamp-pumped dye lasers has been performed. It was revealed the lowest divergence of the laser radiation can be achieved if the temperature of a coolant is somewhat higher than that of an active solution. It was shown that ensuring the high directivity of radiation and efficient operation of the repetitively pulsed flashlamp-pumped dye lasers is possible if a uniform distribution of pumping radiation in the active element is provided, waveguide modes of ray trajectories are damped, and the temperatures of the active element and the coolant are stabilized.

P6

Geometrical optics of axially-symmetric non-uniform amplifying medium

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The analysis determining the divergence of radiation of flashlamp-pumped dye lasers is carried out at a various degrees of heterogeneity of distribution of the refraction index of active medium. It is shown that an excessive compulsory cooling of the outer surface can result in increased divergence of radiation and in reduction of a range of stability of the resonator, and an insufficient cooling in significant decrement of the power parameters of laser. The measures enabling one to optimize the temperature mode of cooling systems of the powerful pulse-periodic dye lasers are determined.

P7

New Program Interface for the Laser Performance Investigation

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A new program interface has been developed as a basic tool for the investigation of semiconductor quantum-well lasers and vertical cavity surface-emitting lasers. It is based on the Beam Propagation Method and intended for interactive design of semiconductor lasers. The program package contains the single-mode steady-state module, and also the modules for the small signal response, and the temperature characterization. All modules take into account the hole burning effects. A graphical user-oriented interface is included to make the program interactive. Besides, on- screen editing of the laser structure and parameters as well as plotting routines for customizing the output results are available.

P8

Dependence of parameters of photodetector on the structure p-i-n diode

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In this paper, an analytical study of a homojunction p-i-n photodiode with nonuniform doping of the p and n regions is presented. Due to nonuniform doping of the p and n regions the electric field is formed in both regions. This field facilitates the carrier transport if it oriented in the right direction, and hence diffusion processes elapse faster. The bandwidth of a homojunction p-i-n photodiode depends on the velocity of diffusion. Due to the acceleration of diffusion process, the bandwidth of a homojunction p-i-n photodiode is improved up to 30 GHz. A comparative analysis of the bandwidth of a homojunction p-i-n photodiode with the protodiode with nonuniform doping of the p and n regions, and a heterojunction p-i-n photodiode is done. As a result of comparison, it has appeared that the bandwidth of the offered photodiode practically does not differ from the bandwidth of the heterojunction p-i-n photodiode, but a homojunction p-i-n photodiode has a higher quantum efficiency.

P9

Application of the Fourie Transformation for the Analysis of the SQW Laser Diode Transfer Characteristics

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In the given work, the problems of application of the numerical method of Fourier transformation in the analysis of the frequency characteristics of a three-level dynamic model of quantum-well lasers are considered. The technique of realization of numerical experiment for studying the transfer characteristics is presented. The availability of the given method for its use in the simulation of any active device of fiber-optic networks is proved.

P10

Two-Dimensional Integral Equations for the Analysis of Optical Waveguides

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Wide usage of optical waveguides in the development of active and passive optical network components requires an adequate full-wave analysis of the structures under the consideration. One of the most efficient methods is the two-dimensional Integral Equation (IE) method using the Green's functions and based on the concept of polarization currents.

In the presented paper, the methods of analysis of two-dimensional dielectric and magnetic structures are considered. The consideration is based upon the two-dimensional IE. The cases of optical wavequide in the free space and in the shielded region with one, two, and four flat metallic shields are studied. The corresponding two-dimensional Green's Functions (GF) are derived for the analysis. The dielectric and magnetic insertions in the structures are considered as electrical and magnetic polarization currents. Therefore, the same analysis can be also applied both for isotropic and anisotropic or even bianisotropic structures. The scattered fields are presented as the integrals via the Green's functions and electric or magnetic fields with the multipliers equal to the difference of permittivity or permiability and unity. The integration is done only over the regions where the permittivities or permiabilities are nonequal to unity. The two-dimensional GF are derived from the three-dimensional ones by integration over the axial coordinate thus reducing the dimensions of GF and IE. The method is useful for multilayered shielded and nonshielded waveguides and easily applied for the lossy media by using the complex-valued permittivities and permiabilities. It can be also applied in the analysis of discontinuities in dielectric waveguides.

Based on the considered method, the analysis of the mode dispersion and the losses in several multilayered planar dielectric waveguides for optical applications have been performed. The results are in a good agreement with the published data and with the results obtained by using the mode matching method.

P11

Comparison of Validity of the Wave and Beam Models of Propagation in the Multiport Floated Fiber-Optic Distributors-Adders

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The principles of operation of the fiber-optic distributors-adders are often explained by either the wave or the beam model.

As a criterion of the model correctness, so-called *V-parameter* is used: $V = \frac{2\pi}{\lambda} a n_1 \sqrt{2\Delta}$, where ***a*** is the core radius; ***n1, n2*** are the refraction indices of the core and the cladding materials; ***Ä=(n1-n2)/n1***. Application area of the beam model is found at ***V≥10***. At ***V<10,*** the analysis based on the solution of Maxwell equations is necessary. Evaluation of ***V*** value for standard and multimode optical fibers (OF) of the "quartz-quartz" type yields the values of 3,2 and 32, respectively. In such a way the choice of the model is determined.

According to the first model, transmission of power from the input port to the output one is realized due to the process of beatings of the natural modes. The values of the coupling between natural modes and the length of the coupling domain determine the optical radial amplitude in each output port.

The second model is based on the beam assumption about the optical flow according to which the radiation distribution is caused by the conditions of propagation inside of the core. In the cladding, the radiation propagates from the core into the volume of biconical area (BCA) and under the further propagation is seized by the output OF core.

The wave approach provides the solution of the problem in two stages: determination of the natural FODA waves and field amplitudes in output ports at the excitation of the given input ports. Parameters of the natural modes are determined from a transcendental dispersion equation in the form of the infinite order determinant. Computer analysis of the problem shows the efficiency of such a wave model at small distances between the OF cores. At the large distances, the coupling between the cores is weakened and the difference between natural modes becomes inessential, phase constants approach so near to one another that revealing each of them becomes very difficult.

In fact, the potentialities of the wave model are limited by the accuracy of calculation of the Bessell functions and also by the accuracy of calculation in the whole. Physically this is understandable and practically justified because at small coupling between the natural modes the area where the transmission of the significant fraction of the input power to the output ports becomes very large. In this case, the efficiency of the transmission of the significant fraction of the input power is determined, generally, by the given inaccuracies in the OF thicknesses and in the distances between them.

Another restriction of the wave models is connected with multimodal propagation and is typical to all the problems of this type.

P12

ACCOUNTING OF SOME RESTRICTIONS FOR THE THRESHOLD SENSITIVITY AND MEASUREMENT ERROR IN THE PULSE FIBER-OPTIC ACCELEROMETERS

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As it was shown before [1], the estimation of metrological potentials of the 3D digital precise accelerometer based on a pulse fiber-optic sensor (FOS) of super low linear accelerations with a pendulum-type sensitive element-modulator (SEM) have been obtained by calculating an ideal SEM model, where some of natural destability factors were neglected.

In the present work, we study the influence of the temperature factors and instability of the pendulum period on the basic accelerometer metrological parameters.

We can affirm that the imposition of the pendulum SEM average heat-energy fluctuation on the kinetic energy does not affect the metrological potentials of an accelerometer.

The heat dilation affects a pendulum SEM parameters in much greater extent, first of all due to its length change. A possible way of correcting such errors is to combine accelerometer and high-precision temperature sensor. Then, during the data processing, it is easy to align the FOS signal with the thermosensor data.

Instability of the SEM pendulum period puts another restriction on the accelerometer metrological performance. This property inherits from the general characteristics of any autogenerator based on an oscilating system with a limited trust value. This sort of errors can be also corrected by a special processing of the FOS signals, e.g. by averaging the measurement data from several cycles. However, such a treatment makes and accelerometer less fast-operating.

Thus, by using a computer FOS-signal proccessing, it is possible to evaluate metrological parameters under the real exploitation conditions.

P13

Principles and methods of electronic and optical gyroscopic devices

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A gyroscope with a rotating solid body satisfies, in general, a problem of navigation of self-contained objects. The minimum measurement error of the anglar velocity equals to ***~0,01 degree/hour***. The limit of the improvement of this value equals to ***~10^{-4} degree/hour***, conditioned by the thermal fluctuations of the mass centre (molecular noises) of the rotatable rotor.

For the self-contained navigation, the sensivity of the mechanical gyroscopes is insufficient and research of new physical principles for navigation systems are being carried out now. Electronic and optical atomic gyroscopes (***AG***) and laser gyroscopes (***LG***) are the most perspective and elaborated ones.

Atomic gyroscopes. The effect of the atom optical orientations is used in ***AG***. The most important characteristic of ***AG***'s is their high sensitivity, which enables one to detect and treat signals from the samples containing ***~10^{9}*** atoms. For comparison, not less than ***~10^{11}*** paramagnetic centers can be registered by using the electronic paramagnetic resonance method and ***~10^{19}*** atomic nuclai can be registered with the aid of the nuclear magnetic resonance method.

Laser gyroscopes. The principle of ***LG*** work is based on the Doppler effect, which is realized in the optical scheme of a circular laser interferometer (gyroscope) based on the Sanjak scheme with the interference of two beam waves, propagating in the laser circuit in the opposite directions.

Under a constant angular velocity ***Ù*** of ***LG*** rotation, the running frequency of the interference maximum (minimum) equals to the double frequency ***2Äf*** of the Doppler shift ***Äf***. The frequencies ***Ù*** and ***Äf*** are connected with each other by the main ***LG*** equation: ***Ù = (pë$_0$Äf)/(4A)***, where ***p*** and ***A*** are the perimeter and the area of the laser circuit; ***ë$_0$*** is the laser radiation wave length. It is expected that ***LG*** can determine the angular velocities less than ***10^{-4} degree/hour***.

The main merits of ***AG*** and ***LG*** are the absence in their measurement space of rotating rotor bearings or other mechanically moving parts, and as a result the absence of the friction problems, the absence of nonbalance of rotor, and increased reliability. The most important working characteristics are: low power consumption (few tens of watt), ability of quick start and also ability to work within the large dynamic rotation-velocity range. At the same time, the principal difficulties of the realization of potentialities of ***LG***'s take place even in the experimental models. They are: the multimode character of laser radiation; phase, frequency and intensity fluctuations of laser radiation; "capturing" of anti-beam wave frequency; "zero departure" of the gyroscope, and others.

P16

BEAM MODEL OF RADIATION PROPAGATION IN BICONICAL AREA OF MULTIPORT FLOATED FIBER-OPTIC DISTRIBUTORS-ADDERS.

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Shaping of the biconical area (BCA) is a basic operation in manufacturing of the multiport floated fiber-optic distributor-adders (FODA) of the optical radiation based on the cable of the optical fibers (OF). This stage determines the main parameters of the future FODA: the level of the losses and the irregularity of the radiation distribution from the input ports between the output ones.

Detailed quantitative analysis of mixing and redestribution of the radiation inside BCA is rather difficult. On one hand, the radiation flow in BCA can be interpreted as propagation of electromagnetic waves in a dielectric waveguide of small length ("wave" approach). At the same time, the main details of the radiation propagation inside BCA is possible to describe completely within the framework of geometrical optics, by using the beam representation of the flow (so called "beam" approach), under which the consideration of the influence of BCA boundaries is a natural result of using the law of reflection and refraction.

As a criterion of the correctness of one or other approach, so called V parameter or normalized frequency [1]: $V = \frac{2\pi}{\lambda} a n_1 \sqrt{2\Delta}$, is used .

If $V \geq 10$, the beam approach yields practically exact results, but at $V < 10$ a full electromagnetic analysis based on the solution of Maxwell's equations is nesessary.

Evaluation of V value for a standard single- and multimode quartz FG yields the values of 3.2 and 32, respectively. This means that in the analysis of radiation propagation in BCA based on the cable made of the multimode OF, the «beam» approach can be used.

The problem was solved by a mathematical simulation of BCA with the aid of computer. For a given geometry of BCA (determined by the length of melting-down area and the value of its sprain), we determined the boundary profiles "BCA - free space" and "core - cladding" for each OF. As an equation for these boundaries, we used a modified equation of the "chain line":

$$y = k \cdot Ch \frac{x}{m}$$

Here, constants k and m are determined from the conditions:

$$R = k \cdot Ch \frac{A_0}{m}; \quad R^2 A_0 = \int_0^A y^2 dx,$$

where R is the cable radius; $2A_0$ is the length of the melted area; $2A$ is the length of the formed BCA.

After this, by using the refraction and reflection laws, each ray leading to BCA from each input of OF was traced. Discretization of entering the rays in BCA was assumed as follows: angular one (within the aperture corner of each input OF): 1^0; along the spatial coordinate (within the core diameter of the each input OF): 5μm. Under such conditions, the following results of the beam passing through BCA were registered: a) going beyond the boundaries of BCA (in the free space); b) getting in the cladding of OF at the output from BCA; c) getting in the core of OF at the output from BCA. The data of such a simulation enabled us to calculate the main working parameters of the simulated FODA. By analyzing the dependences of the calculated parameters of FODA on the geometric parameters of BCA, recommendations concerning the choice of optimal floated lengths and the values of real FODA were given.

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P17

Absolute cryogenic receiver as a standard laser radiation receiver

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The problem of improving the accuracy of the design of a thermodynamic temperature dial is one of the timely problems of metrology of temperature measurements. In this connection, a radiometric method opens new perspectives in measuring the temperatures from 0^0 C up to 1000^0 C.

The given paper considers the design and basic technical characteristics of the cryogenic thermal receiver of optical radiation with electrical substitution. The device operation is based on the principle of a flow calorimeter with controlled heat distribution. The reception cavity is a thin-walled copper case whose interior surface is covered with millo. Two heating windings are placed on the outside surface. The bringing wires are manufactured from superconducting titanium-niobium alloy. The temperature of heating of the cavity is monitored by a semiconducting voltage converter. For the cryogenic radiometer it was possible to improve essentially the performance due to the high heat conductivity of copper at the temperature of liquid helium, sharp reduction of radiation losses, and usage of superconducting wires. As evaluatings show, the magnitude of the threshold power does not exceed 10^{-9} watts, the radiative emmitance is 0.9994, the integrated factor of transformation is 1000 volt/watts, and the range of the measured powers is within 10^{-5} to 10^{-4} watts. The time constant of the device is 30 seconds.

The high metrological performance of the designed cryogenic receiver-radiometer opens the way for improving the accuracy of photometric and spectroradiometric measurements. Particularly, a calibration of a primary photometer and a development of the national primary standard unit of the intensity of light.

P21

ANALYTICAL APPROACH TO THE FINE STRUCTURE OF DIFFRACTION ANOMALIES IN THE RESONANCE DIFFRACTION

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It is well known that the light diffraction on well-conducting surfaces may lead to the great variations in the properties of diffracted waves if one of the diffracted waves is close to the surface electromagnetic wave (SEW) or surface plasmon-polariton. For some values of the grating parameters this resonance excitation of SEW leads to the total absorption of the incident wave by a well-reflecting surface, strong changes in the polarization of the specular wave, or essential power redistribution among the diffraction orders. Although these effects are known, the complexity of the problem makes it difficult to investigate them in the general geometry (conical diffraction) and for arbitrary periodic gratings. The majority of theoretical works deal with sinusoidal gratings and the simplest (planar) geometry and (or) use numerical methods of investigation.

In the paper, we present analytical investigation of the problem in the general geometry and for arbitrary gratings. Besides of the further development of general analytical approach, the cell shape influence on the resonance fine structure is under consideration. In particular, it is shown that interaction of resonance waves via inter-resonance grating harmonic results in essential qualitative changes of resonance structure even for the small harmonic amplitudes. This may cause, for instance, destruction of the total suppression of the specular reflection effect.

A simple analytical approach to the resonance diffraction problem presented makes it possible to analyze both known and predict new effects interesting in theory and technical applications.

P22

Transformation of polarization through the resonance diffraction

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The transformation of polarization in the scattering of electromagnetic waves from a highly reflective diffraction grating under Wood's resonance condition is investigated theoretically. The transformation coefficients of the polarization components of the incident and reflected waves are found on the basis of the resonance diffraction theory. The conversion effect from one to another polarization depending on the grating parameters, and experimental conditions are investigated in detail.

P23

MODELING OF PROCESSES IN ELECTROCHEMILUMINESCENCE EMITTING DEVICES AND THEIR APPLICATIONS

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The electrogenerated chemiluminescence (ECL) is a light-emitting phenomenon that arises during electrolysis of many organic compound solutions. It found a successful utilisation in the ECL emitting devices. On the other hand, ECL has applications in the physical and chemical analysis in ecology, chemistry, biology, medicine, immunoassays. ECL quanta are emitted by the electronically excited molecules of pointed compound products of homogeneous solution chemical electron-transfer reactions. Those reactions kinetics and mechanism depend strongly not only on the ECL composition nature, electrolyte and solvents, but in greater extent on the ECL cell (volumetric or thin-layer) configuration, electrolysis mode (pulsed or direct current/voltage), etc. The mathematical modeling and numerical simulation to solve mass-transfer problems in thin-layer electrolyte-free cells are presented. In particular, simulation was performed for thin-layer cells with homogeneous electron-transfer reactions between electrogenerated analyte particles followed chemical reactions: a typical case of ECL analysis (ECLA). To verify our numerical modelling, assays of water probes contaminated by some polycyclic arenas by developed analytical "ELAN-2" apparatus and methods were carried out. Quite good agreement was noticed in a number of experiments, obtained divergences are discussed also. Results of mathematical modeling and numerical simulation can be useful in the other ECLA applications, e.g., in an ECL immunoassay in the flow-injection mode.

P24

TOTAL SUPPRESSION OF THE SPECULAR REFLECTION THROUGH THE RESONANCE DIFFRACTION FROM HIGHLY REFLECTING SURFACE

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The light diffraction on highly conducting surfaces may result in the Wood-type anomalies for some values of the grating parameters. These peculiarities are caused by the resonance excitation of the surface electromagnetic wave (SEW) when some diffracted orders are close to the SEW. Till the recent years, the complexity of the problem makes it difficult to obtain the results in explicit analytical form. However, the wide field of physical applications such as nonlinear surface optical effects, grating and medium parameter measurements, and optical and optoelectronic devices design also makes the problem timely and of great interest.

In the paper, we present a detailed analysis of some aspects of the problem, namely, one of the strong resonance effects: that of the total suppression of specular reflection (TSSR). On the basis of essential improvement of the earlier presented resonance diffraction theory, we analyze TSSR in the case of single (both in planar and general geometry) and double resonance case (close to normal incidence). The grating parameter values necessary for TSSR existence are found in the both cases. The method presented enables one to consider shallow gratings of arbitrary profile, with both relief and media optical parameters modulation including arbitrary double resonance case in a general geometry.